IMPLEMENTING SIGNAL SUPPORT PRINCIPLES ON THE BATTLEFIELD OF THE FUTURE

A MONOGRAPH
BY
Major Daniel R. Kestle
Signal Corps

School of Advanced Military Studies
United States Army Command and General Staff College
Fort Leavenworth, Kansas

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Major Daniel R. Kestle

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Approved by:

_______________________ Monograph Director
LTC Deborah D. Gregoire, MS

_______________________ Director, School of Advanced Military Studies
COL Danny M. Davis, MA, MMAS

_______________________ Director, Graduate Degree Program
Philip J. Brookes, Ph.D.

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ABSTRACT

IMPLEMENTING SIGNAL SUPPORT PRINCIPLES ON THE BATTLEFIELD OF THE FUTURE by MAJ Daniel R. Kestle, USA, 53 pages.

The US Army appears to be at a crossroads in the evolution of warfighting. This change has begun to manifest itself in the ever increasing digitization of the force. The success or failure of this "new" force lies in the ability of advanced digital equipment to pass information. Establishing communications networks to support information transfer throughout the force warrants a renewed analysis of the doctrinal foundations upon which signal support is based. This monograph examines the doctrinal foundations of signal support and examines the viability of implementation on future battlefields.

The methodology of this monograph is twofold. First, the principles of signal support are examined to establish their validity. This is accomplished by presenting the doctrinal definition of the principles and investigating their foundations under the auspices of the evolution of communications. The second area of inquiry requires establishing reasonable parameters for the characteristics of the future battlefield. A review of the two foremost theories of future conflict is presented to cull common characteristics germane to the battlefield. With signal support principles validated, and a feasible projection of the characteristics of the future battlefield, an analysis is conducted. Analysis entails qualitatively assessing the implementation of the principles of signal support across five "eras". Projecting the analysis into the future reveals principle adequacy or shortfalls on the future battlefield.

A key finding of this monograph is the increasing vulnerability of communications sites. Technological advances appear to enhance implementation of three of the four principles of signal support (i.e., continuity, versatility, and simplicity). However, technological advances are also improving emitter detection, targeting, and engagement. As forces digitize, communications assets to link them will proliferate. The research presented in this monograph suggests that the ability to ensure physical security of these signal sites appears to declining. Overlooking this aspect of the future battlefield could have catastrophic consequences for the future force.

TABLE OF CONTENTS

I. Introduction

"Congress can make a general, but only communications can make him command."
General Omar Bradley[1]

There is currently much consternation over the direction the US Army is heading. Much of the debate hinges on how to tailor a force to meet an amorphous opponent on an ill defined future battlefield where technology will apparently have a prevailing role. Regardless of the composition of the future force or its mission, that it will have a commander and a command and control (C2) system in support is axiomatic.

A critical element of a command and control system is communications. Communications can be thought of as the neural network that animates the martial body to action. Today, communications networks permeate the military from the highest echelons to the lowest. As forces digitize, it is reasonable to believe this trend will continue. Establishing communications networks in support of the force has long been predicated on four signal support principles. A network implementing these principles increases its viability potential. In the face of rapidly advancing technologies will communications providers be capable of implementing the principles of signal support on the future battlefield? This is the question this monograph aims to answer.

In answering this question two areas warrant examination. First, the validity of the principles of signal support is reviewed. This is accomplished through historical analysis of the evolution of communications. The author determined five "eras" that illustrate

significant changes to communications. From these eras, communications network performance can be evaluated to determine how well the communications system supported the warfighter under the auspices of the principles of signal support. The second area of examination entails determining the characteristics of the future battlefield. To do this, a review of the "recognized" experts is conducted. These experts include professional periodicals and journals, military publications, and futurists. Examining each expert's prognostications in turn should reveal generally agreed upon characteristics of the future battlefield. It is reasonable to assume that these characteristics represent the best divination available today and are feasible. These characteristics will serve as an acceptable baseline for subsequent analysis.

Analysis consists of templating each era's comparable ability to implement the principles of signal support. Establishing plausible trends of the past and present should provide a sensible trajectory into the future.

This research question is pertinent to all leaders in the military. Now, more than ever, communications devices proliferate the services. It appears technological advances will provide electronic connectivity to more locations over greater distances and at a faster rate than ever before. Creating a responsive, survivable, synergistic network from the glut of gadgetry may be one of the greatest challenges to the Army as it leans forward into the Information Age. As will be shown, a key finding of this research suggests that communications site survivability in the future may require renewed consideration. Without communications *you* can not command.

II. Communications Principles

> "Opportunity is of great advantage in all things, but especially in war; and among the several things which have been invented to enable men to seize it, nothing can be more conducive to that end than signals."
>
> Polybius (204 BC to 122 BC)[2]

Signal providers strive to provide the warfighter reliable communications. The continuum of signals providers range from the SIGO (Signal Officer) at the separate battalion and brigade, to the J6 within each Unified Command, and ultimately to the Defense Information Systems Agency (DISA) at the national level. Today, more than ever, providing communications support is a complex business. The reason is threefold: the requirement to provide long range (i.e., strategic—global) coverage; the plethora of available and often incompatible technologies; and the spectrum of communications responsibility.[3] To assure reliable communications in the face of this complexity, the Army developed fundamental precepts to measure signal support adequacy.

The Army fundamentals of signal support are principles which advocate information flow. Because information is synonymous with communication, the principles of signal support will heretofore be referred to as the *principles of communications* for ease of understanding.

The principles of communications have a long standing in the Army as the criteria to providing successful communications support. FM 24-1, Signal Support to the Airland Battle states "[t]hese principles support the information flow among all force elements

regardless of function, service, or nationality." In a nut-shell, FM 24-1 espouses the immutability of the principles of communications regardless of the level of war or the participants. Can these principles be taken at face value? Are they logical and valid criteria? The aim of this chapter is to examine their validity and set the stage for their use as criteria to evaluate their relevance on the battlefield of the future.

An examination of the validity of the principles of communications requires a two pronged effort. First, a thorough understanding of each of the principles must be attained. The subsequent section of this chapter accomplishes this through a review of current military doctrine and definition. Secondly, and perhaps more importantly, a sensibility check of the principles must be reached—do the principles make sense? To do this the evolution of communications is traced. The aim is to glean warfighters' command and control needs, under the auspices of communications, and the response of the signals provider. At the conclusion of this chapter, the principles of communications and whether or not their are valid will be clear.

The Principles of Communications

The fundamentals of signal support are based on operational principles. These principles (i.e., principles of communications) provide signals planners a yard-stick to determine the adequacy of communications support. The more principles adhered to in a communications plan the more successful the communications network. Implementation of the principles requires understanding. The capstone document for the principles of communications is FM 24-1.

FM 24-1 identifies four principles: ***continuity***, ***security***, ***versatility***, and ***simplicity***. Each principle encompasses several sub-components. The general concept of each principle and their subordinate elements warrant examination in turn.

Continuity. "Continuity is the uninterrupted availability of information paths..." This concept requires a communications path be available to all warfighting forces regardless of location or posture (i.e., static or mobile). The four subordinate elements of continuity are survivability, reliability, redundancy, and connectivity.

To communications planners these sub-elements mean the network must be robust. The network must be able to: function after sustaining combat losses (survivable); provide effective and quality information (reliable); provide alternate paths for information flow (redundant); and ensure all units are electronically linked (connectivity).[4] "Assured access" is the term currently in vogue to capture this concept.

Security. Security refers to the physical security of the network communication sites, protection of information, and exploitation of electromagnetic emissions. The four subordinate elements of security are information security (INFOSEC), physical security, dispersion, and deception.

This concept evokes protection. The network must support: procedures to safeguard information (INFOSEC includes communications security (COMSEC) and electronic security (ELSEC)); concealed, camouflaged, and defensible communications sites (physical security); geographically separation of both signals sites and the forces being supported (dispersion); and leveraging electromagnetic emissions to either deny or allow the enemy interception in support of deception operations (deception).[5]

Versatility. Versatility is a capstone term that captures principles of war in the signal arena. Like a maneuver operations planner, the signal planner must design a network that identifies the objective, aggressively supports that objective (i.e. initiative), masses assets to support the mission, and allows for expansion and contraction of the network.[6] The aim is to provide a network that supports the warfighter's operation without impinging on the forces' agility, initiative, or their synchronization. In this light it is easy to see why flexibility, inter-operability, and autonomy are versatility's sub-elements.

The three sub-elements focus signal planners' support on forces potentially operating in rapidly changing circumstances. The communications network must: anticipate force dispositions and requirements—flexibility in asset emplacement and employment achieves this; ensure procedures, systems, and equipment are compatible (inter-operable); and provide the equipment and communications links to support commanders operating in stand-alone mode (autonomy).[7]

Simplicity. Simplicity means just that. The simpler equipment and procedures the easier to implement under the strains of combat (hence the idiom KISS (Keep it Simple, Stupid)). The challenge to implement this principle increases proportionally with the tempo of operations, availability of advanced technologies, and the spectrum of combatants (i.e., joint and combined operations). The communications network must be designed to support simplicity in installation, operation, and maintenance (IOM).

To support this principle, network planners focus on two sub-elements: technological sophistication and standardization. Technological sophistication directs

planners to be cognizant of the level of equipment available to the user and plan networks that exploit technological automation capabilities yet minimize sophistication turbulence. Because of the confluence of divergent force technologies, exemplified in both joint and combined operations, planners must ensure uniformity (i.e., standardization). Standardization ensures compatibility from the tactical to the strategic level and provides the warfighter the ability to synchronize forces and operations.[8]

The four principles—***continuity***, ***security***, ***versatility***, and ***simplicity***—in concert, act as commander's intent for the communication network planner. In laymen's terms: if the network can electronically link all forces, safeguard the signal, remain flexible enough to realign in support of rapidly changing operations, and facilitate IOM then the probability that the network will successfully support the warfighter is significantly increased.

The above clearly defines current communications principles. The question that begs to be asked is "Are they sound?" To answer this, an examination of communications evolution is necessary. During this excursion it is important to keep in mind that martial communications is in general a reflection of a civilization's technological capabilities tailored to meet the warfighter's methodology.

The Evolution of Military Communications

There are, in this author's view, five eras that illustrate dramatic changes in military communications. For lack of better terms, they are antiquity, Napoleonic, terrestrial electromagnetic, radio, and the digital era. The aim in examining each era is to

understand the methodology of warfare and what communications techniques were applied, and trace the evolution of the principles of communications. This approach will not only verify or refute the validity of the principles of communications, but provide a trajectory for probable characteristics of the battlefield in the information age.

Antiquity (3500 BC to circa 1800)[9]. This era is characterized by numerous changes in warfare methodology. The methodology evolution ranges from tribal warfare, to the phalanx, the Roman Legion, the advent of cavalry, siege-craft, Fredrican warfare, and the introduction of gunpowder weapons. Although warfare evolved, the communications system throughout the era remained relatively unchanged.

In general, this broad swath of time was marked by well armed, and armored, men marching in mass to clash with like clad foes on the field of battle. Throughout this era the battlefield was relatively small. Commanders were able to observe not only the disposition of their entire force, but that of the enemy. Once forces were set into motion the ensuing melee was often uncontrollable. The control a commander could exert on battlefield action, typically limited to the employment of his reserve, was dependent on an unobstructed view of his forces—what he could see he could influence. A clear visual path enabled the commander to observe the action and relay commands to subordinates. If the commander could see his forces his forces could probably see him. Accordingly, establishing a clear line of sight (LOS) was paramount to command and control on the battlefield of antiquity.[10]

Commanders typically positioned themselves on high ground overlooking the battlefield to establish unhindered LOS. From a height they could more easily observe and

direct the action. With small forces in a limited area communications was easily achieved with visual and audio signals. These crude yet effective devices included raised weapons, battle flags, unit identifiers (e.g., legion standards, personal pendants, colored uniforms, etc.), and signal torches. However, visual cues are easily obscured by haze, dust, and smoke. To overcome these shortfalls, visual signals were supplemented with audio cues. Audible signals included drums, trumpets, and voice commands. To provide further redundancy to the warfighter's communications system, messengers were often used.[11]

Thus a commander on high ground with signaling devices close at hand was capable of effective command and control. Although these communications arrangements proved adequate at the tactical level, they were cumbersome in supporting the strategic. Visual and audio relays were established to link the tactical to the strategic level, but the typical, and most secure method was the use of the messenger.[12] In 490 BC, the news of the victory of the Athenians over the Persians at the Battle of Marathon was relayed to Athens in this manner.[13]

Throughout this era armies continued to grow in size. As armies became larger the engagement area increased accordingly. This strained both the commander and his communications system. Gustavus Adolphus was relegated to rushing around the battlefield to ensure his forces were properly synchronized. A technological advance, the telescope, allowed Frederick the Great to once again position himself on high ground to overlook the battlefield.[14] Although commanders adapted themselves to the demands of the expanding battlefield, the communications system was not. The communications

system of visual, audio, and messenger remained unchanged from the days of the *hoplites*.[15]

It is apparent that all of the principles of communication have their roots in this era. **Continuity** was paramount in providing connectivity to the forces. Physical **security** was ensured by the proximity to the commander, who was typically in a centralized and relatively safe position.[16] **Versatility** was a non-issue. The close quarters of the area of operations allowed flexibility. Battlefield chaos, limited technological advances, and mixed nationalities drove the need for signals which were easy to operate and interpret. Visual and audio signals are about as **simple** as they get.

At the end of this era, the size of armies had hit critical mass. A commander was no longer capable of observing all his forces in combat and effectively wielding them. A command and control (C2) system, supported by effective communications had to be developed. It would take the genius of Napoleon to implement the next development in C2.

Napoleonic (1800 AD to 1850 AD). The Napoleonic Era ushered in the concept of the nation in arms. Never before had such large armies taken to so lethal a battlefield. Although social upheaval provided the catalyst for this phenomenon, the beginnings of the industrial revolution made it possible. The monster army, made from the masses and supported by industry, needed but a brain to set it motion. The brain, establishing a neural network unsurpassed, was Napoleon.

As mentioned previously, through the late 1700's, command was dependent on the leader's ability to observe the battlefield and his forces. As the size of forces and their

dispersion increased, a commander was no longer capable of surveying the entire battlefield. As an example, Frederick the Great was often able to exercise direct command of all his forces from a static location overlooking the battlefield. However, fifty years later, during the Jena Campaign, Napoleon was unable to observe the entire field of battle and take direct action.[17] Commanders were no longer capable of observing the depth and breadth of the battlefield. The migration of the commander away from direct observation (line-of-sight) of the battlefield and his forces taxed not only basic command and control, but the communications system as well. The geographical displacement of the commander from his forces now hampered immediate transmission of information. This challenge to communications still exists today.

Napoleon recognized the difficulties of coordinating an army of which he had no direct visibility. To overcome this he organized the *Grande Armee* in a revolutionary manner and developed the first modern staff.[18] The implications to communications were subtle. Although the same communications means (i.e., visual, audio, and messenger) were applied, there was a dramatic increase in traffic of written documents, and the distance over which they had to be transported. Literate staffs and pentathlon winners were aggressively sought after.

The military characteristics that the communications system had to adapt to included more and widely dispersed forces, and an increase in weapons range and lethality. It appears as though the principles of communications were teetering at the abyss. The distances between forces at the operational and strategic levels were pushing **continuity** to the breaking point. Messengers were capable of providing INFOSEC, but their

physical **security** was compromised by the range and lethality of weapons. The messenger system employed was tenuous at best with regard to **versatility**. Flexibility was limited to route selection. Other than that, messengers were effectively "fire and forget" missiles—there was no way to recall them. The one success for the principles of communications was **simplicity**. The devices and procedures were simple and understood by all.

Napoleon made the *Grande Armee* monster walk, talk, and besmirch the countryside. But other creators were watching and learning. They would create monsters too, but theirs would be bigger and faster. Communications would need a radical innovation to keep pace. This innovation would come with the harnessing of the electron.

Terrestrial Electromagnetic (1860 AD to 1916 AD). This military characteristics of this era include increases in operation tempo, force size, and battlefield lethality. The US Civil War, the Austro and Franco-Prussian wars, and the first World War describe the progress evolution of these characteristics. From the communications aspect, this era entails the advent and inculcation of revolutionary electronic communications technologies.

The Civil War, perhaps more than any other conflict during this era, provides a focal point at which the traditional method of warfare and the modern model begin to diverge. Prior to the Civil War, combat was characterized by large massed infantrymen grandly advancing toward each other, firing until close enough to bring the bayonet to bear. This scene continued to be played out during much of the Civil War. However, the Civil War marked a radical departure from the previous method of warfare in two ways: the vast geographical separation of areas of operation (AO) and the tremendous number of

forces involved; and a logarithmic increase in lethality. The first instance dictated the need for operational art to synchronize large and dispersed forces, the second revitalized the utility of the defense in the form of trench warfare.[19]

The Prussians, under the direction of Helmut von Moltke, continued to accelerate the dispersion of forces. This phenomena is best illustrated in the mobilization, initial dispersion, and then concentration of Prussian forces during the Austro and Franco-Prussian wars. Whereas Napoleon, in 1813 at the Battle of Leipzig commanded 180,000 troops, the Prussians at the Battle of Koniggratz commanded upwards of 460,000—an increase of two-hundred-fifty percent in just over fifty years!

Trends in combatant increases and dispersion continued to prevail through World War I. However, warfare methodology stagnated. The initial combatants, Germany and France mobilized tremendous numbers of men, 2.4 and 1.3 million, respectively.[20] As the war settled into stalemate and trench warfare, the defensive forward trace of battle on the western front ran nearly 500 miles from the coast of Belgium to the northern boarder of Switzerland.

Technological advances during World War I include improvement in artillery, machine guns, chemical warfare, the airplane, and use of motorized and tracked vehicles. These war machines were capable of producing casualties undreamed of a few years before. Technology and the mass of humanity on the battlefield produced casualties in one battle that exceeded the entire Prussian force engaged in the wars of forty years earlier (e.g. Battle of Verdun—978,000, first Battle of the Somme—1,265,000).[21]

Battlefield characteristics of this era are self evident: the size of forces employed increased; armies operated over increasingly larger areas of terrain; and technology facilitated wholesale slaughter. The challenge to the signals provider was to support a warfighter that was wielding large masses of men over vast areas. Technological innovation, harnessed by the warfighter for its destructive capability, would also have to be leveraged to support communications advances.

Signal advances in this era are characterized by the transition from audio/visual to the use of terrestrial electromagnetic signaling(i.e., wire). To signals providers, supporting the warfighter called for a communications system that was capable of operating over geographically extended operational boundaries, and facilitating coordination and synchronization of widely dispersed forces. The telegraph was the first technological advance capable of meeting these demands. In fact, the telegraph marked the first noteworthy advance in long distance communications in a millennium.[22]

Although the electric telegraph has roots as far back as 1753, it was not until the US Civil War that it was used effectively by a military force on a large scale.[23] Its use in support of military operations was refined by the Prussians under the direction of von Moltke the elder with telling results. However, as armies began to move faster over greater distances, installation of the telegraph was hard pressed to keep pace.[24] Often commanders relied upon previously installed civilian and railroad telegraph lines to support their operations. The draw back to the telegraph was the time it took to position the wire to protect it. Because wire was not insulated, it was elevated to reduce the chances of the electromagnetic signal from grounding out—not to mention the damage

caused by terrestrial traffic and saboteurs. To overcome these shortfalls, signals technology build upon the telegraph and branched out in several directions to support the warfighter.

During World War I signals innovations included the telephone, wireless telegraphy, the airplane, and the radiotelephone.[25] However, trench warfare lent itself to land line communications. Accordingly, it is the sound-powered telephone and spaghetti wired switchboards supporting the "Chateau Generals" that are often called to mind when thinking of communications of this era.[26]

The military characteristics the communications system had to adapt to included more and widely dispersed forces, and an increase in weapons range and lethality. Because of the static nature of this era the principles of communications were more easily implemented. Although distances between forces at the operational and strategic levels continued to increase over the previous era, the advent of the telegraph improved **continuity**. The use of wire communications allowed signal assets to support from the rear enhancing physical **security**. A variety of signaling devices (i.e., audio, visual, pigeon, and messenger) allowed for a degree of **versatility**. Technology, although "new", was easily operated by anyone literate. Thus **simplicity** continued to be implemented in this era.

Static warfare was generally easy to support from a communications perspective, but the costs of trench warfare in manpower and materiel were catastrophic for the nations involved. Mobility and initiative would have to be restored to the battlefield. Accordingly, the signals community would have to develop and refine emerging

technologies to support the warfighter on the emerging battlefield. The technology that would come to the forefront was, of course, the radio.

Radio (1916 to 1965) The radio era covers the initial development of radio technologies in the early 1900's through the US's involvement in Vietnam. Battlefield trends, and the resultant communications developments, are aptly gleaned from reviewing the characteristics of European Theater in World War II and the initial stages of conflict in Vietnam.

National and military leaders alike were appalled by the losses suffered on the battlefields of Word War I. Breaking the deadlock of trench warfare would require adapting emerging technologies and developing tactics for their application. One of the greatest technological advances to change the face of modern warfare was the refinement and adaptation of the internal combustion engine.

The internal combustion engine provided a mobility and operational tempo that was nothing less than revolutionary. It was the Germans who first recognized the potential of this new technology, and, under the hand of Heinz Guderian, were capable of building a tank and mobile army juggernaut. The tactic of their employment was of course termed *blitzkrieg*—lightening war. The challenge was developing the necessary control apparatus for such widely dispersed, large, and fast moving forces. The solution came from Guderian himself, who insisted that all German tanks be equipped with the best command facilities (i.e., radios).[27] The subsequent German success may in large part be due to Guderian's earlier service as an assistant Signals Officer to the Headquarters of the German Fourth Army.[28]

The new found mobility of armies is the hallmark of World War II. Examples of speed on the battlefield abound: Germany's attacks into Poland and France; Rommel's operations in North Africa; Patton's drive to relieve Bastogne; etc. Although the allies adapted to this mobile battlefield, they were far less successful in developing communications equipment to support it—it was not until 1944 that the US Army fielded tactical radios capable of transmitting up to 100 miles.[29]

Mobility and communications enabled theater commanders to control forces from Scandinavia to the Mediterranean. Extended areas of operations, advances in armaments, and the number of forces involved led to astronomical casualties. In comparison, World War I resulted in 6.6 million combined deaths, World War II losses are estimated at near 60 million (all theaters).[30]

Communications advances continued from World War II through the Korean conflict and into the early 1960's. The focus of this development was on strategic and field communications. The apex of development was during the initial stages of the Vietnam conflict.

The battlefield characteristics of Vietnam provided several challenges to the signals providers. The country and type of warfare created an environment where there was no perceivable front line trace, the terrain was rugged, force dispersion increased, and coordinating inter-service air support was vital. These constraints necessitated numerous and dispersed fixed stations, proliferation of radio retransmission facilities, electronic bridges and gateways from the tactical to both the operational and strategic levels, and an

increase in inter-service compatibility. The warfighter wanted reliable communications and he got it, at a price.

To provide the warfighter a continuous and robust communications system, signal architects developed a redundant network. The communications network expanded from the traditional Frequency Modulated (FM) radio net to a complex intertwining of Amplitude Modulation (AM), Pulse Coded Modulation (PCM), tropospheric scatter (i.e., troposcatter), and the first appearance of satellite in support of combat operations. However, the majority of these systems were cumbersome and failed to provide the warfighter a flexible and adaptive system. There was a manning bill to pay, too. Due to the technical nature and dispersion of communications facilities, a large signal contingent was necessary. By the end of 1970, over four percent of the entire US armed forces (i.e., Army, Air Force, Navy, Marines) in sector were US Army Signal personnel.[51] These monolithic systems, and the associated manning requirements, proved to be insupportable under the restructuring of the Army in the 1970's and 80's.

The battlefield characteristics of this era are marked by increased force participation, dispersion, and mobility. Increases in lethality were due primarily to longer reach, improved targeting, and advanced munitions.

Signal development during this era was driven by two factors. First, the radical employment of fast moving forces (i.e., first mechanized then air mobile). And secondly, technological advances were necessary to establish an effective means for controlling these forces. The development and application prompted the first, while the advent of the radio

provided the solution to the second. How does this relate to the principles of communications?

In this era, as in the previous, communicators had to adapt to a warfighting methodology that entailed more and widely dispersed forces, and an increase in weapons range and lethality. The principles of communications were tenuously implemented. The advent of the radio in conjunction with wire communications did improve **continuity**. However, the tempo of battle and force dispersion drove signal assets forward to accompany combat forces. And, although technological advances such as ENIGMA promoted information security, physical **security** was degraded. Tempo also adversely effected **versatility**. If radio communications were lost, there were no responsive back-up systems. In general, the nature of radios did support **simplicity**. The challenge of manufacturing and maintaining radios was demanding. This was primarily due to the sensitivity of tube and crystal components. However, at the user level, "push to talk" was as simplistic as it gets. If you could operate an on/off switch and speak, you could operate a radio.

Digital (1965 to present). The digital era emerged during the Vietnam conflict with the introduction of long-haul communications and computerized management devices. Some of these advances include electronic warfare (EW), combat intelligence and battlefield automation, and precision guided munitions (PGM).[32] From the communications aspect a brief review of digital application during Vietnam and Desert Shield will provide the flavor of this era.

The battlefield characteristics of Vietnam had not changed perceivably by its later stages. There still was no clear front line trace. Areas of operation typically had strong points established from which troops would deploy. The situation was much like the American Indian wars where the frontier was sprinkled with forts. the difference during Vietnam was that troopers would sally forth in helicopters instead of on horseback.

Isolated cantonment required an extensive communications network. The communications network eventually spanned the entirety of South Vietnam. By 1969 the first ever employment of modern automatic switching equipment for both voice and message traffic, and satellite communications in a combat zone had been realized.[33] Although this extensive network was modern it required numerous relay and retransmission stations. The net effect was isolated and vulnerable signal sites.[34]

The interim years between Vietnam and Desert Shield saw a boom in computerization and miniaturization. In part this was driven by the advancement of digital electronics. Previously analog electronics was the workhorse. Analog technology relied on bulky and unreliable vacuum tubes and conventional electronic gadgetry (i.e., mechanical resistors, transistors, anodes, diodes, etc.). Solid-state technology produced printed circuit boards (PCB). PCBs have proven to be more reliable, easier to maintain, and are adaptable to small packaging. All of these advantages would come to the forefront during Desert Shield/Desert Storm.

Desert Shield/Desert Storm best demonstrates the current digital capability of this era. Technological advances were apparent throughout the coalition and ran from terrestrial to space applications (e.g., Abrams tanks, laser guided munitions, UAVs,

spaced based assets). These advances marked two distinct departures from previous warfare: lethality throughout the area of operations, and mobility.

Weapons and munitions advances allowed Allied forces to conduct precision strikes across the Iraqi spectrum—tactical, operational, and strategic—simultaneously. The Iraqi's, although not practiced in striking across the continuum of war were capable of long range strikes with Scud missiles.[35] The net effect of both combatants' capabilities was the creation of a battle zone that negated safe-havens. Weapons capable of striking across the breadth and depth of the battlefield forced even the most remote support troops to operate as though they were on the front line.

The second characteristic of this warfare was an increase in mobility. Fully mechanized and mobile forces allowed movements in depth that had never before been possible. In 100 hours US forces penetrated deep into Iraq and cut through approximately 43 Iraqi divisions.[36]

The battlefield characteristics of this era promulgate those established by the previous. Vietnam and Desert Shield/Desert Storm illustrate the characteristics of an increase in forces engaged, dispersion of forces, rate of movement, and lethality.[37]

Signal response in this era was driven by lessons learned during the Vietnam conflict and the subsequent implementation of Airland Battle Doctrine. During Vietnam the signals system was too cumbersome to support the warfighter. This was due to technical limitations in establishing a communications network that could integrate from the tactical to the strategic level. The result was the development of Mobile Subscriber Equipment (MSE). MSE was more capable of supporting the warfighter on the move and

providing communications gateways to all echelons and dispersed forces. MSE was validated during Desert Shield/Desert Storm.

The net effect of signals advances on the ability to implement the principles of communications is yet to be determined. However, generalities can be gleaned. The use of various radios (e.g. FM, AM, single channel ground air radio system (SINCGARS)) in conjunction with MSE and satellite communications has clearly improved **continuity**. However, the tempo of battle and force dispersion continues to drive signal assets forward to accompany combat forces. Although technological advances such as frequency hopping and signal encryption has promoted information security, physical **security** continues to be a challenge (i.e., technology continues to improve triangulation and weapon's engagement ranges—not a good combination for signal site survivability). Increasing maneuver tempo appears to degrade **versatility**. The lead divisions during DS often outran MSE coverage. The back-up systems in these instances were TACSAT (tactical satellite) and AM. And although these systems are not the preferred method of communications they are effective nonetheless. The principle of **simplicity** is more difficult to gauge. The nature of technology being fielded is sophisticated, however, push-to-talk is still the norm. From a user's aspect communications continues to be relatively simple. At the network manager's level communications network installation is daunting. However, automation tools are under development to facilitate network design and management. Digitization has also eased the previously complex task of electronics maintenance. Many transmitters now come with self diagnostic packages. These

packages enable an operator to identify faulty circuit boards and replace them with relative ease.

Recapitulation

Doctrinal principles for the employment of signal assets in support of the warfighter are found in FM 24-1: Signal Support in the AirLand Battle. FM 24-1 states that the four principles of signal support are "**continuity**, **security**, **versatility**, and **simplicity**."[38]

Communications should allow the commander to contact and relay his directives to his subordinates (**continuity**), safeguard the information and the signals asset (**security**), be capable of adapting to the situation (**versatility**), and provide ease of operation (**simplicity**). Are they sound? Absolutely! Based on the previous historical review it is easy to understand the evolution of these principles. They make sense. Will the signals community be capable of implementing them on the future battlefield? To answer that an examination of the possible parameters of the future battlefield must be conducted.

III. The Future Battlefield

> "Armed conflict will be as prevalent on this planet in the next quarter century as it has been since the dawn of history. There were 654 identified instances of major organised [sic] armed conflict in the 265 years 1720-1985, of which 162 started in the years 1951-85. It is highly unlikely that the incidence of conflict will diminish..."
>
> Chris Bellamy[39]

The aim of this chapter is to determine probable characteristics of the future battlefield. Although no one can predict the future with certainty, there are two trains of thought that establish generally recognized expectations: the Revolution in Military Affairs (RMA); and the Information Age. By examining both venues, generally agreed upon characteristics of the future battlefield can be culled with reasonable assurity.

Revolution in Military Affairs

There is currently a debate raging over what constitutes a Revolution in Military Affairs (RMA) and whether the US is in the middle one. For the purposes of this monograph, the eventual results of the debate are moot. The discourse of the debate does however, shed light on two aspects that are relevant to understanding communications on the future battlefield. First, what are the characteristics of the battlefield of the future—participants in the debate are struggling to determine the nature of the future battlefield. Secondly, the perception of an RMA is driving changes today that will impact on the structure of our forces tomorrow. Current, and often subtle, changes will reverberate forward in time. It will be the challenge of the future warfighter to adapt their C2 network

from communications equipment being developed and fielded now. It is a combination of the future battlefield environment, the warfighter's methodology and requirements, and technological advances that will drive how communication support is executed in the future. So what are the general characteristics of the future battlefield and what are the foreseeable technological advances to respond to the warfighter's C2 needs? The aim of this section is a firm understanding of this idea from the RMA aspect. To meet this end, this section briefly reviews the definition of RMA and presents common characteristics of previous RMAs.

What is an RMA

To provide an RMA understanding of depth and breadth, one must thoroughly review the litany of literature available. In general, there are four recognized arenas of discussion at the forefront. These are military based studies and journals, official publications, and non-fiction books. The principle publishers of the first three are readily identified: the Strategic Studies Institute, Joint Forces Quarterly, and Training and Doctrine Command's Pamphlet (TRADOC PAM) 525-5. Establishing a "leader" in the realm of non-fiction books is more difficult, however, an attempt will be made. Reviewing each source in-turn should establish a "unified field theory" for the RMA.

The Strategic Studies Institute (SSI) is one of the premiere players in the RMA debate. In the last three years it has published no less than eight studies on the RMA.[40] This flood of discussion illustrates the difficulty in grappling with the RMA concept. However, many have made inroads.

Cooper states in his study that "all revolutions are marked by discontinuous change."[41] His definition, though dictionary accurate, is too restrictive for the RMA and has not received support from other researchers. In general, there appear to be two, not mutually exclusive, spheres of description for RMA. One entails the use of strategic level broad term factors of social, economic, political, and military.[42] The other is more military specific (i.e., revolution increases combat effectiveness) and uses the factors of technical change, systems development, operational innovation, and organizational adaptation.[43] Regardless of the description, all studies agree on one thing—technology alone is not driving the revolution.

There are numerous military journals that frequently publish articles on the RMA. Of interest, for the purposes of this monograph, are how the sister-services view RMA and the communication ramifications of an RMA. A review of Joint Forces Quarterly (JFQ) Spring '97 will suffice for the former, the latter is addressed later.[44]

The Spring 1997 JFQ does not encapsulate service parochial views; however, it does provide some insight into them. This edition, in particular, is noteworthy because of its focus on the RMA and essays representative of each of the services. The RMA essays were penned by a Navy Captain, an Air Force Lieutenant Colonel, and an Army academician. Although each essayist certainly had a service "flavor" (i.e., system-of-systems, high performance platforms, and land power, respectively), they all agreed on one aspect. This common thread is the idea of information warfare.

In each case, the essayists agree that future information warfare is heavily dependent on technological advances. Do the services currently have the technological

capable to effectively prosecute information warfare? No! The technological leap required does therefore lend credence to the idea that we are on the verge of military "revolution". To these "independent" essayists, it is evident that technological advances are not *the*, but certainly one of the predominant factors in the RMA.

The above views provide a good start point for examining the RMA. However, the official military view is essential to this examination. What is the Army's official position on the RMA?

TRADOC PAM 525-5: Force XXI Operations, A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century, is the Army's attempt to peer into future conflict. This pamphlet, without explicitly stating it, is projecting a future force based on the RMA. The Army of the future, it indicates, will be shaped by global strategic interests (i.e., political factors), evolving doctrine, and an expected "thousand-fold advance [in information technology] over the next 20 years."[45] Again, technology is clearly a significant factor in this "revolution".

The final leg in the search for a theory of the RMA resides in non-fictional books. There are several books that brush-up against the RMA, but all fail to bring it to terms. Two that this author feels come closest, are the Tofflers' War and Anti-War, and one that is somewhat more controversial, Douglas Macgregor's Breaking the Phalanx. The Tofflers' concept is slightly askew from the traditional RMA and is discussed in the Revolutionary Waves section of this chapter.

In Breaking the Phalanx Macgregor, although somewhat distancing himself from the RMA debate, provides some revealing insights into the RMA. He states that

"organizational change in Armies can produce revolutionary change in warfare."[46] He contends that RMAs occur not because of technological advances, but because of the way Armies employ the technology in their organizations, tactics, and at times their concept of war.[47] Macgregor makes it clear that technology is an *impetus* for revolutionary change and must be leveraged across the spectrum (i.e., tactical, operational, and strategic level) in conjunction with a new warfighting approach. Although Macgregor has a different perspective on the role of technology in an RMA, it is an integral player nonetheless.

To say that the RMA is less than explicit is an understatement. There are several cited historical instances of RMAs that may help clarify at least qualitatively what a military revolution is. Authors typically refer to two eras of RMA—antiquity and modern. Although antiquity RMAs are generally agreed upon (e.g., the Macedonian phalanx and the Roman Legion), consensus on modern RMAs is lacking.[48] Modern RMAs cited, to name a few, include Napoleonic Warfare, American Civil War, Franco-Prussian War, Crimean War, Russo-Japanese War, World War I, *Blitzkrieg*, World War II, introduction of long range nuclear weapons, and Desert Storm. In each case there are common characteristics that identify these conflicts as revolutionary.

In broad terms each revolution was characterized by a marked increase in size of forces fielded, tempo of operations, and battlefield lethality over the preceding warfighting methodology. Many of these characteristics are touched upon in Chapter II above. One of the underlying threads in each one of these revolutions is technology. Technological advances allowed for the arming and sustainment of larger forces, increased mobility of forces, and the enhancement of munitions range, precision and lethality. The RMA

visionaries predict a continuance of these trends with a liberal increase in reliance on technological advances in information technology. To lend credence or refute these prognostications it is necessary to examine civilian visionaries. Currently, the most prolific appear to be the Tofflers and their theory of "revolutionary waves."

Revolutionary Waves

The authority for the concept of the information age is indisputably the Tofflers' War and Anti-war. The Tofflers' premise is anchored to three paradigms, First, Second, and Third Wave revolution—agrarian, industrial, and information, respectively. Each of these waves represent a revolution in human advancement. Of interest to this monograph is their description of military capabilities in each of the revolutionary states. In their book they state that a military revolution "occurs only when an entire society transforms itself, forcing its armed services to change at every level simultaneously—from technology and culture to organization, strategy, tactics, training, doctrine, and logistics."[49] Given their definition and the number of revolutionary paradigms, military revolutions have only occurred twice (i.e., during "wave" transformations).[50]

The Tofflers refer to the information age as the third wave revolution. They assert that the United States and other advanced countries are currently in the throes of this third wave transformation. To understand what the third wave is, it is first necessary to understand the first two.

The first wave encompasses the agrarian age and third world countries. This wave, and cultures still in this stage of development are characterized by an economy

dominated by agricultural production. The agrarian age is typified by the earliest social groupings and still exists in some societies today. "Everywhere in First Wave societies, warfare was about food."[51] The current military capabilities of a nation in this state of development is typically limited to tribal weaponry and some small arms (e.g., Aidid's "technicals" in Mogadishu would welded weapons from clubs to rocket propelled grenades).[52] The Tofflers state that First Wave wars were characterized not only by the technology available, but by the agrarian culture's ability to organize, lead, and prosecute warfare.[53]

The second wave entails the industrial age and industrialized nations. This wave is characterized by economies largely dependent upon the mass production of products. The industrial wave was ushered in during the French Revolution. Industrialization allows for the mass production and standardization of armaments. Industrialized warfare is best illustrated by the warfighting methodology that existed during World War II—massed produced tanks and airplanes rolling off the assembly line and into battle. An example of a current industrial wave society is Iraq. The second wave reached its zenith towards the end of World War II. The terminus for the expansion of industrialized warfare was reached with the advent of nuclear weapons. The Tofflers assert waging war without employing nuclear weapons provided the impetus for the third wave revolution.[54]

The Third Wave—Information Age

The Tofflers assert that the apex of humanity thus far, the industrialized civilization, is coming to an end.[55] The birth of the new civilization will create tension

with the preceding two types and most likely result in conflict. As proof they offer the results of the historical development of second wave (industrial) societies.

As stated earlier, agrarian societies are based on agriculture; accordingly their wealth is tied to the land. Food keeps the society and army fed and ensures cultural viability. It goes without saying that this society needs fertile land and hands to work it. Industrial societies are based on factory production, their wealth determined by output and consumption. Second wave societies require manpower, raw materials, and markets. The needs of each wave will bring the two civilizations into conflict. As an example, the advancement of second wave powers during the 1800s launched the waging of colonial wars.[56] Whereas agrarian conflicts were typically local and of relatively little significance, industrial conflicts can be waged globally with catastrophic consequences.

Today we are on the verge of the creation of a third wave civilization that is dominated by the computer. Wealth for this wave will be based on the ways in which knowledge is created and exploited. The assertion is that bottom rung civilizations (i.e., agrarian) will supply foodstuffs and mineral resources, mid-tier (industrial) will provide cheap labor and mass production, and the dominant societies will be information based. This trisected world will experience the turmoil caused by each societies economic needs—"and hence political and military."[57] The new form of warfare waged by third wave civilizations was heralded during Desert Storm.

Desert Storm is held up as the cross-over from second wave to third wave warfare. During the conflict both wave warfare methodologies was applied. Second wave methodology was represented by pragmatic weapons (e.g., "dumb" bombs) and was

typical attrition warfare. Third wave warfare was exemplified by the proliferation of "smart" weapons and the initial attacks on command and control facilities across the breadth and depth of the battlefield. The success of these attacks highlights the need to maximize one's own knowledge base (know the enemy's disposition and intent, and spread the information liberally) and degrading your opponent's (prevent him from knowing your disposition and intent, and deny him the ability to coordinate his forces).[58] Although Desert Storm provided the first glimpses of third wave warfare, the Tofflers paint a graphic picture of technological advances in the future ranging from the mundane to the exotic.

The Tofflerian future battlefield is describes one clear overall direction of change. A battlefield where weapons will have "finer and finer precision, more and more selectivity...One target, one kill."[59] General characteristics of this battlefield include the absence of a clear front-line trace, smaller more lethal forces, complex integration of all forces, a robust electronic infrastructure supporting the force (much of it from space), and unprecedented speed.[60] All of these changes are predicated on third wave technological advances. The Tofflers see the application of these technologies and force appearing more frequently in Low Intensity Conflicts (LIC) like Somalia, Bosnia, and Zaire.[61]

Will there continue to be mixes and matches between the waves in combat? Yes. The Ranger/Delta force raid in Mogadishu is a clear example of third wave technologies applied against an agrarian level opponent. It is reasonable to assume these type conflicts will continue in the future. However, if one believes the Tofflers, the results of a war

between unlike waves is typically insignificant; global catastrophe occurs when like waves wage war.

Characteristics of the Future Battlefield

The above review of academicians, military professional and official publications, and futurists reveals generally agreed upon characteristics of the future battlefield. The dominant catalyst for change to the battlefield is technology. Technology is, and will continue to enhance the effects of precision fires and thus increase lethality. Lethality drives commanders to disperse their forces to reduce casualties. Dispersed forces require increased mobility to allow them to concentrate. In very broad terms, these prognostications are sensible and acceptable. What does this mean to the signals provider?

Communications Capabilities

Regardless of the situation, the warfighter demands effective communications support. Communications providers lean heavily upon the principles of communications to determine the effectiveness of their communications network. The principles of communications are, by definition, immutable. The environment and equipment in which future communicators will have to implement them is not..

The environment of the future battlefield will be dynamic. Communicators must anticipate supporting widely separated forces operating under mobile conditions.

Sophistication of enemy radio intercept, direction finding, targeting, and engagement will appreciably increase. Under these conditions, a static communications facility is an anathema. The ability of signals providers to support the warfighter in the future hinges largely upon the equipment being procured now.

The list of communications technologies currently under development and field testing is exhaustive. However, a brief review of the characteristics of existing and planned US Army communications technology should set the stage for subsequent analysis on the signal provider's ability to implement the principles of communication on the future battlefield.

Within the brigade/battalion level, the primary means of communications is Combat Net Radio (CNR).[62] CNR consists of three primary systems: Improved High Frequency Radio (IHFR), SINCGARS, and Single-channel TACSAT. Command Post communications from separate battalion, to brigade, division, and echelons above corps (EAC) are provided by the MSE system. MSE provides voice/data transmission paths for telephone (Digital Non-secure Voice Telephone DNVT, and Digital Secure Voice Telephone DSVT), radio telephone (Mobile Subscriber Radio Telephone), and Net Radio Interface (NRI, enables CNR to be patched into MSE system). Theater communications is a conglomerate of communications assets from US forces and allies, the existing infrastructure, host nation, commercial leased, Chairman of the Joint Chiefs of Staff (CJCS) controlled, and strategic assets. In general, the most mobile and responsive communications are found at the lower levels. Communications assets at the theater level are typically large, high capacity, static facilities.

The fundamental characteristic of communications at all levels is, of course, electronic emission. CNR, MSE (back-bone links for both echelon below corps (EBC) and EAC), and satellite communications links are accomplished with the use of radio electronic emissions. Radio links are optimized when there are no obstructions between the transmitter and receiver. In the past this has meant positioning signals assets on high ground to improve line-of-sight and range. However, improving broadcast paths also increases probability of intercept (POI) and direction finding by the enemy. To enhance line-of-sight and reduce POI, communicators are experimenting with Unmanned Aerial Vehicles (UAV) retransmission platforms.

UAVs have the potential to act as "virtual" high ground for emitters. The latest tests on the medium altitude Predator reveal that this concept is plausible. The Predator is capable of operating up to an altitude of 45,000 feet and has a loiter time of up to 40 hours. Communications test packages have demonstrated the ability of covering an area of 193 kilometers by 113 kilometers. At its maximum altitude, the Predator is capable of communicating with the ground at up to ranges of roughly 240 nautical miles.[63] Future UAV communications packages, referred to as HAE UCN (High-Altitude-Endurance UAV Communications Node), will be able to carrying multi-functional payloads (e.g., multi-band, multi-mode), and be capable of cross-linking between aircraft.[64]

The use of UAVs is only one of the plethora of communications advances being explored. Others, to name a few, include meteor burst communications, improved bandwidth utilization, encryption, and the use of civilian commercial satellite telephones. Will they ensure the signals providers ability to implement the principles of

communications on the future battlefield? The next chapter presents an analysis to determine just that.

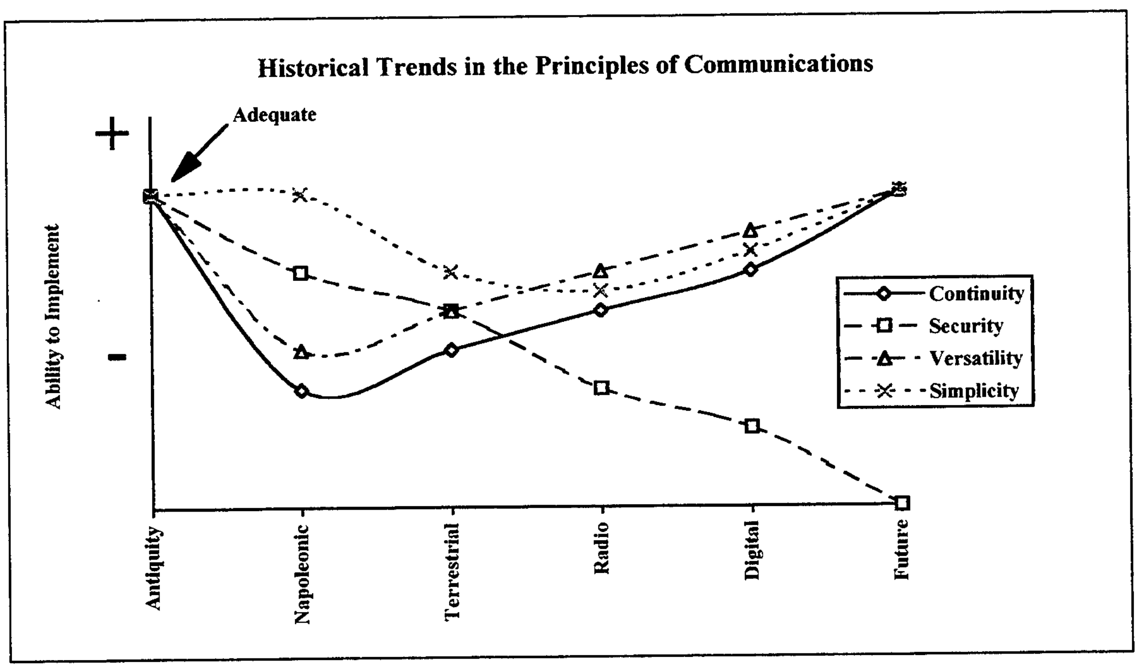
IV. Conclusion

"[During] conventional war...we must also expect an increase in the threat of physical attack by sabotage or heliborne raiding parties against known communications vital points...damage by conventional artillery/rocket attack against tactical communications can be expected...we must anticipate there will be temporary isolation and fragmentation of our own forces."

John Markam[65]

Analysis

Communications support is based on four principles: **continuity**, **versatility**, **simplicity**, and **security**. The evolution of these principles have led to their axiomatic inclusion in US Army doctrine. Below is a qualitative comparison of the signals providers' ability to implement the principles of communication throughout the ages and into the future.



Continuity. Communications connectivity to forces was adequate during antiquity. In this age, a field commander had line-of-sight (LOS) with all of his forces because of the limited size of the battlefield. In later eras, continuity initially suffered as technological advances failed to keep pace with rates of movement and force dispersion. Nadir for this principle is depicted during the Napoleonic era. Although the Napoleonic era is characterized by a revolutionary massing and dispersion of forces, communications continued to be tantamount to those of antiquity. Implementing continuity improved in subsequent ages. Technological advances provide for redundant communications paths to ensure connectivity. During Desert Shield/Desert Storm, the communications network provided redundant communications via MSE, FM, AM, and TACSAT. It is reasonable to believe that the introduction of new communications devices in the future will enhance the implementation of this principle.

Versatility. Flexibility of communications systems was unchanged from antiquity through the Napoleonic era (i.e., audio, visual, and messenger systems were the extent of redundancy). As force mass and dispersion increased, the ability of the communications system to rapidly adapt to changing circumstances degraded. Nadir for versatility, as with continuity, occurred during the Napoleonic era. The revolutionary boom in numbers of forces and their dispersion rendered redundant communications virtually non-existent. The advent of first land-line and then radio communications did restore some flexibility, but given rates of advance and the increasing number of forces involved, these devices were still incapable of providing a network that was flexible and responsive. Versatility has slowly improved as technological advances restored mobility to communications

devices (e.g., MSE). It is feasible to anticipate that the continuing proliferation of varying types of communications devices will enhance flexibility in the coming years.

Simplicity. Simplicity follows the general trend lines of continuity, and versatility. Communications systems during antiquity and the Napoleonic era were the manifestation of simplicity. Visual, audio, and messenger services under the immediate control of the commander were responsive and simple. Simplicity degraded as technologically advanced systems were introduced. As societies become more technically adept, and devices are designed to promote ergonomics and user-friendly interfaces, simplicity to the user is on the up-swing. It is plausible that technological advances will continue to provide the user devices that present the appearance of simplicity. Arguably, integrating the gamut of communications devices into a synergistic network is daunting to network planners. However, if planned and executed properly, the system will appear simple to the user.

Security. Security entails INFOSEC, COMSEC, ELSEC, and physical security. Technological advances in transmission, cryptography, and TTPs (tactics, techniques, and procedures) have clear application in enhancing INFOSEC, COMSEC, and ELSEC. What is less clear is the ability to provide physical security in the face of advance detection, targeting, and engagement capabilities. Although the implications of physical security on the future battlefield are difficult to predict, there is an apparent trend—survivability of communications sites has continued to degrade. During antiquity, communication site survivability was ensured by location. Communications were in close proximity to the commander. Commanders were typically located in a position of relative

safety. Accordingly, the communications system was survivable. As force mobility and dispersion increased, communications sites have had to locate either directly with combat units or, due to LOS requirements, on progressively more exposed positions (typically high ground) to ensure continuity. In either case, communications sites have become more vulnerable. Technological advances in emitter detection and targeting have exacerbated this phenomenon. Desert Storm is a case in point—Iraqi communications sites were easily detected and targeted. It makes sense that this trend will continue into the future as technological advances improve acquisition and deep strike. Thus, the adequacy of physical security to promote site survivability, more than all other communications principles, is in question on the future battlefield.

Findings and Implications

Accurately predicting future events is a fantasy. Analysis can however reveal patterns that are feasible as trajectories for future possibilities. The above analysis has shown that the principles of communications are valid tools to assist communications planners establish communications networks. Forward looking signals providers should be cognizant of the potential characteristics of the future battlefield and prepare now to implement the principles of communications upon it. Analysis of the leading experts in future conflict revealed common expectations of the future battlefield. These include an increase in force size, dispersion, and movement rates, and lethality. Technological advances appear to be responding to the warfighter's needs with regards to the first three characteristics. However, there does not appear to a technological advance capable of

ensuring signal site **security** in the face of the ever increasing lethality of the battlefield.

This is perilous short-coming that must be examined and solved now.

ENDNOTES

[1] US Department of the Army, Field Manual 100-5 Operations, (Washington, DC: GPO, June 1993), 2-15.

[2] David L. Woods, A History of Tactical Communication Techniques, (New York: Arno Press Inc., 1974 (reprint)), 1.

[3] Under the concept of IMA (information management area), signal support disciplines include communications, automation, visual information, records management, and printing and publications. See US Department of the Army, FM 11-43 The Signal Leader's Guide, (Washington, DC: Government Printing Office, June 1995), 1-1 for an IMA overview and US Department of the Army, FM 11-75 Battlefield Information Services (BIS), (Washington, DC: GPO, September 1994) for more detail.

[4] US Department of the Army, FM 24-1 Signal Support in the AirLand Battle, , (Washington, DC: GPO, 15 October 1990), 2-1 to 2-2.

[5] FM 24-1, 2-2 to 2-4.

[6] FM 100-5 Operations, 2-4 to 2-6.

[7] FM 24-1, 2-4 to 2-5.

[8] Ibid., 2-5 to 2-6.

[9] The selection of the year 3500 BC is based on the work of Ernest R. Dupuy and Trevor N. Dupuy, The Encyclopedia of Military History, (New York: Harper and Row, Publishers, 1970), 1.

[10] US Department of the Army. FM 5-33 Terrain Analysis, (Washington, DC: GPO, 11 July 1990) Glossary-8, LOS is defined as "intervisibility between two points located on the earth's surface."

[11] Woods, 1-2.

[12] Ibid., 5.

[13] Rebecca R. Raines, Getting the Message Through, A Branch History of the US Army Signal Corps, Army Historical Series (Washington, DC: GPO, 1996), 3.

[14] Martin Van Creveld, Command in War, (Cambridge, MA: Harvard University Press, 1985), 10-11.

[15] *Hoplites* were the soldiers of the Greek phalanx. For a discussion on the evolution (i.e., Greek, Macedonian, and Roman) and employment of *hoplites* and the phalanx see Dupuy, 16-102.

[16] There are of course instances where a commander's centralized position did not ensure security. One example of this is King Harold who in 1066, during the Battle of Hastings (Senlac),was mortally wounded when he caught a chance arrow in the eye. See Dupuy, 288.

[17] Van Creveld, 10, 95.

[18] Ibid., 72.

[19] Examples of the emergence of trench warfare include the Battles of Vicksburg and Richmond, and the elaborate system surrounding Corinth. For the first two see Bruce Catton, Grant Moves South. (Boston, MA: Little, Brown and Company, 1960), 451-470, and Bruce Catton, Grant Takes Command. (Boston, MA: Little, Brown and Company, 1969), 306-345, respectively. For a description of Corinth see Geoffrey Perret, Ulysses S. Grant, Soldier & President. (New York: Random House Inc., 1997) 212:226.

[20] Dupuy, 931, 933.

[21] Numbers reflect combined casualties for both sides. Dupuy, 960, 961

[22] Van Creveld, 104.

[23] Woods, 105, 108.

[24] During the Civil War the Union did develop a horse-drawn telegraph train that was capable of installing ten miles of wire in four hours. Kenneth Allard, Command, Control, and the Common Defense, (New Haven: Yale University Press, 1990) , 61.

[25] Woods, 125.

[26] JFC Fuller, Generalship: Its Diseases and Cures, (Harrisburg, PA: Military Service Publishing Co., 1936).

[27] Heinz Guderian, Panzer Leader, (Washington DC: Zenger Publishing Co., 1979) 31.

[28] John Keegan, Guderian, (New York, NY: Ballantine Books, Inc., 1973) 6, 42, 49-50.

[29] Woods, 232.

[30] Ernest R. Dupuy and Trevor N. Dupuy, The Encyclopedia of Military History, Fourth Edition (New York: Harper and Row, Publishers, 1993), 1083, 1309.

[31] Thomas M. Rienzi, Vietnam Studies, Communications-Electronics 1962-1970, (Washington, DC: DA, US Government Printing Office, 1972; reprint, 1983), 142, 148.

[32] Allard, 138.

[33] Rienzi, 129 and Raines, 374.

[34] Two examples of the vulnerability of signal sites during the 1968 Tet Offensive are described by Raines, 376-377.

[35] Norman Friedman, Desert Victory, The War for Kuwait, (Annapolis: Naval Institute Press, 1992, third printing with update), 365.

[36] US DOD, Conduct of the Persian Gulf War, Final Report to Congress, (Washington, DC: GPO, 1992), 254.

[37] As an example, US force strengths during Vietnam peaked at 543,000 in the spring of 1969 (see Raines 380), Desert Storm saw 380,000 US troops (see Dupuy, fourth edition, 1479) and the Iraqis at 545,000 (see Final Report to Congress, 254).

[38] FM 24-1, 2-1.

[39] Chris Bellamy, The Future of Land Warfare, (New York: St. Martin's Press, 1987), 1.

[40] The eight studies are: Jeffrey R. Cooper, Another View of the Revolution in Military Affairs, (Carlisle Barracks, PA: SSI, US Army War College, April 1994); David Jablonsky, The Owl of Minerva Flies at Twilight: Doctrinal Change and Continuity and the Revolution in Military Affairs, (Carlisle Barracks, PA: SSI, US Army War College, May 1994); Michael J. Mazarr, The Revolution in Military Affairs: A Framework for Defense Planning, (Carlisle Barracks, PA: SSI, US Army War College, 10 June 1994); Michael Howard and John F. Guilmartin, Two Historians in Technology and War, (Carlisle Barracks, PA: SSI, US Army War College, 20 July 1994); Paul Bracken and Raoul Henri Alcala, Whither the RMA: Two Perspectives on Tomorrow's Army, (Carlisle Barracks, PA: SSI, US Army War College, 22 July 1994); Steven Metz and James Kievit, The Revolution in Military Affairs and Conflicts Short of War, (Carlisle Barracks, PA: SSI, US Army War College, 25 July 1994); Earl H. Tilford, The Revolution in Military Affair: Prospects and Cautions, (Carlisle Barracks, PA: SSI, US Army War College, 22 June 1995); Steven Metz and James Kievit, Strategy and the Revolution in Military Affairs, From Theory to Policy, (Carlisle Barracks, PA: SSI, US Army War College, 27 June 1995).

[41] Cooper, v.

[42] Metz, RMA and Conflicts Short of War, 2-3.

[43] Metz, Strategy and the RMA, From Theory to Policy, 3.

[44] See: James Stavridis, "The Second Revolution," Arsenio T. Gumahad, "The Profession of Arms in the Information Age," and James J. Schneider, "Black Lights: Chaos, Complexity, and the Promise of Information Warfare," JFQ 15 (Spring 1997): 8-13; 14-20; 21-28, respectively.

[45] TRADOC PAM 525-5, Force XXI Operations, A Concept for the Evolution of Full-Dimensional Operations for the Strategic Army of the Early Twenty-First Century, (Ft Monroe, VA: DA TRADOC, 1 August 1994), 1-1 to 1-5.

[46] Douglas A. Macgregor, Breaking the Phalanx, A New Design for Landpower in the 21st Century, (Westport, CT: Praeger Publishing, 1997), 5.

[47] Ibid., 32.

[48] For RMAs of antiquity see Cooper, 13, and Macgregor, 1-2.

[49] Alvin and Heidi Toffler, War and Anti-War Survival at the Dawn of the 21st Century, (New York: Little Brown and Company, 1993), 32.

[50] Ibid., 29.

[51] Ibid., 35.

[52] See Kent Delong and Steven Tuckey, Mogadishu! Heroism and Tragedy, (Westport, CT: Praeger Publishers, 1994), and Kenneth Allard, Somalia Operations: Lessons Learned, (Washington, DC: National Defense University Press, 1995).

[53] Toffler, 37.

[54] Ibid., 42.

[55] Ibid., 18.

[56] Ibid., 20.

[57] Ibid.

[58] Ibid., 68.

[59] Ibid., 72.

[60] Ibid., 67-80.

[61] Ibid., 93.

[62] US Department of the Army, FM 11-41 Signal Support: Echelon Corps and Below, (Washington, DC: GPO, 18 December 1991), 4-8.

[63] Clarence A. Robinson, "High-Capacity Aerial Vehicles Aid Wireless Communication," Signal, vol. 51, no. 8 (April 1997): 16.

[64] Marilyn McAllister and Samuel Zabrdac, "High-altitude-endurance UAVs pick up communications node," Army Communicator, vol. 21, no. 2 (Spring 1996): 21-22. Note: multiband refers to the capability of providing communications payloads to support several bands (e.g., FM, VHF, or UHF); multimode refers to the ability to act in several modes (e.g., retransmission station, relay, or direct link); cross-linking is the ability of a UAV to communicate with other UAVs.

[65] James M. Rockwell (editor), Tactical C3 for the Ground Forces, AFCEA/SIGNAL Magazine C3I Series, vol. 4, (Washington, DC: AFCEA International Press, 1986), 173.

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